US011041444B2

(12) **United States Patent**
Redford et al.

(10) **Patent No.: US 11,041,444 B2**
(45) **Date of Patent: Jun. 22, 2021**

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(54) **GAS TURBINE ENGINE WITH DIFFERENTIAL GEARBOX**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 146 days.

(21) Appl. No.: **16/179,252**

(22) Filed: **Nov. 2, 2018**

(65) **Prior Publication Data**

US 2020/0141326 A1 May 7, 2020

(51) **Int. Cl.**

F02C 7/36	(2006.01)
F02C 6/08	(2006.01)
F02C 7/32	(2006.01)
F02C 7/10	(2006.01)
F02C 3/06	(2006.01)

(52) **U.S. Cl.**
CPC ***F02C 7/36*** (2013.01); ***F02C 6/08*** (2013.01); ***F02C 7/10*** (2013.01); ***F02C 7/32*** (2013.01); *F02C 3/06* (2013.01)

(58) **Field of Classification Search**
CPC F02C 7/10; F02C 7/32; F02C 7/36; F02C 3/06; F05D 2220/50; F16H 3/62; F16H 3/666
See application file for complete search history.

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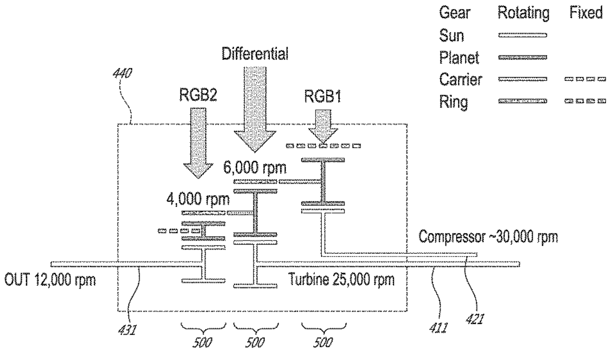
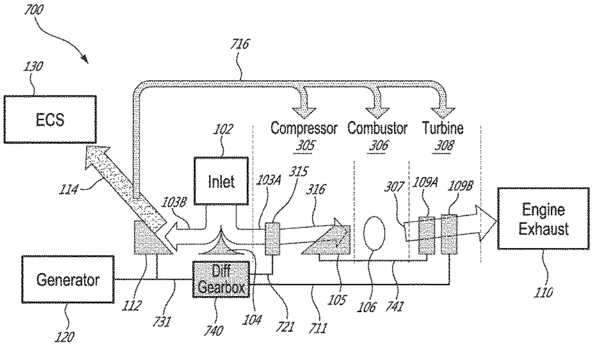
(57) **ABSTRACT**

A gas turbine engine system includes a boost compressor configured to compress air; a combustor in which the compressed air is mixed with fuel and ignited to generate a stream of combustion gases; and a turbine configured to extract energy from the combustion gases, the turbine being drivingly coupled to the boost compressor and to an output shaft via a differential gearbox configured to apportion an input torque from the turbine between a first output torque applied to the output shaft and a second output torque applied to the boost compressor.

10 Claims, 10 Drawing Sheets





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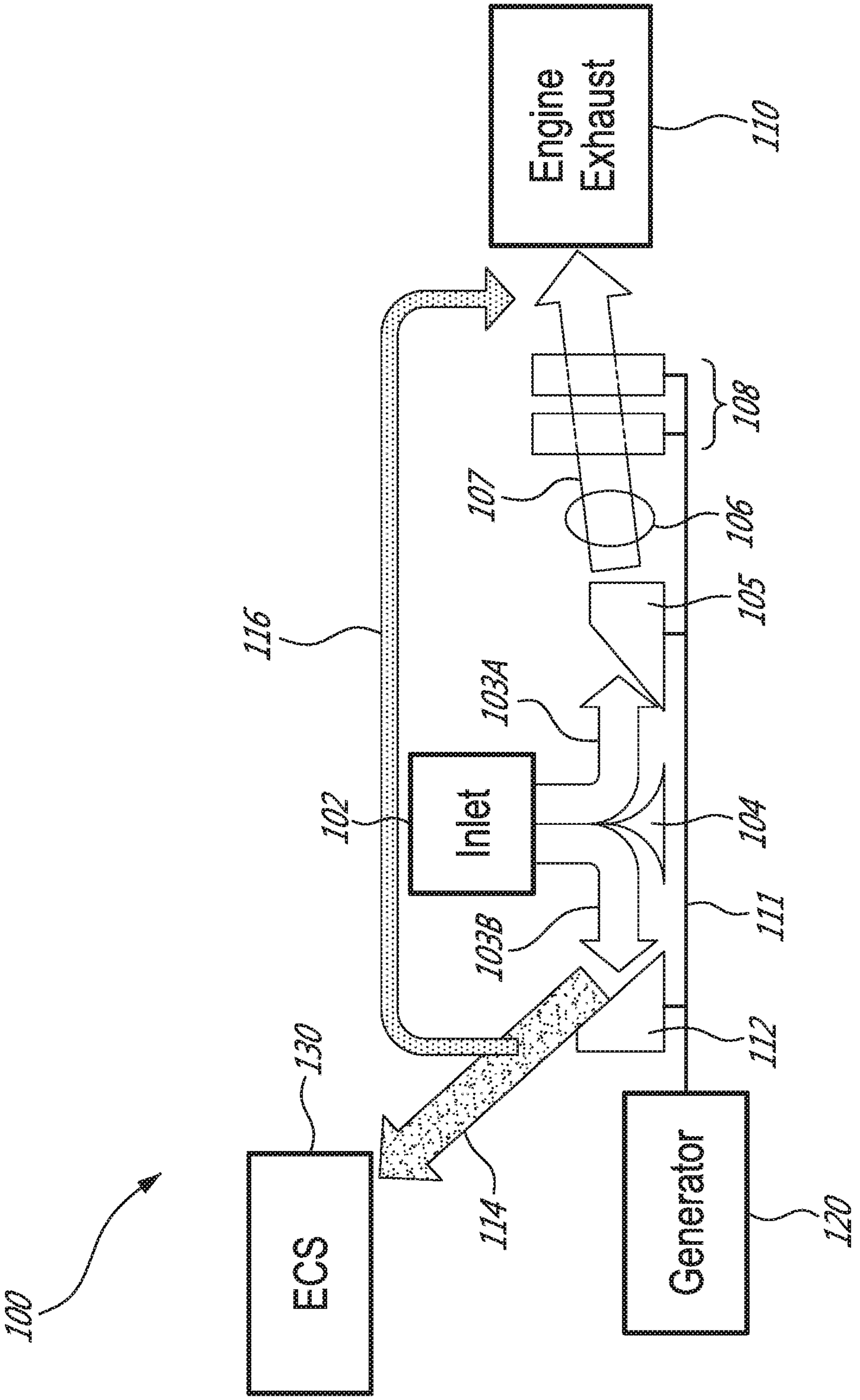
Engine Exhaust
Inlet
ECS
Generator

FIG. 1

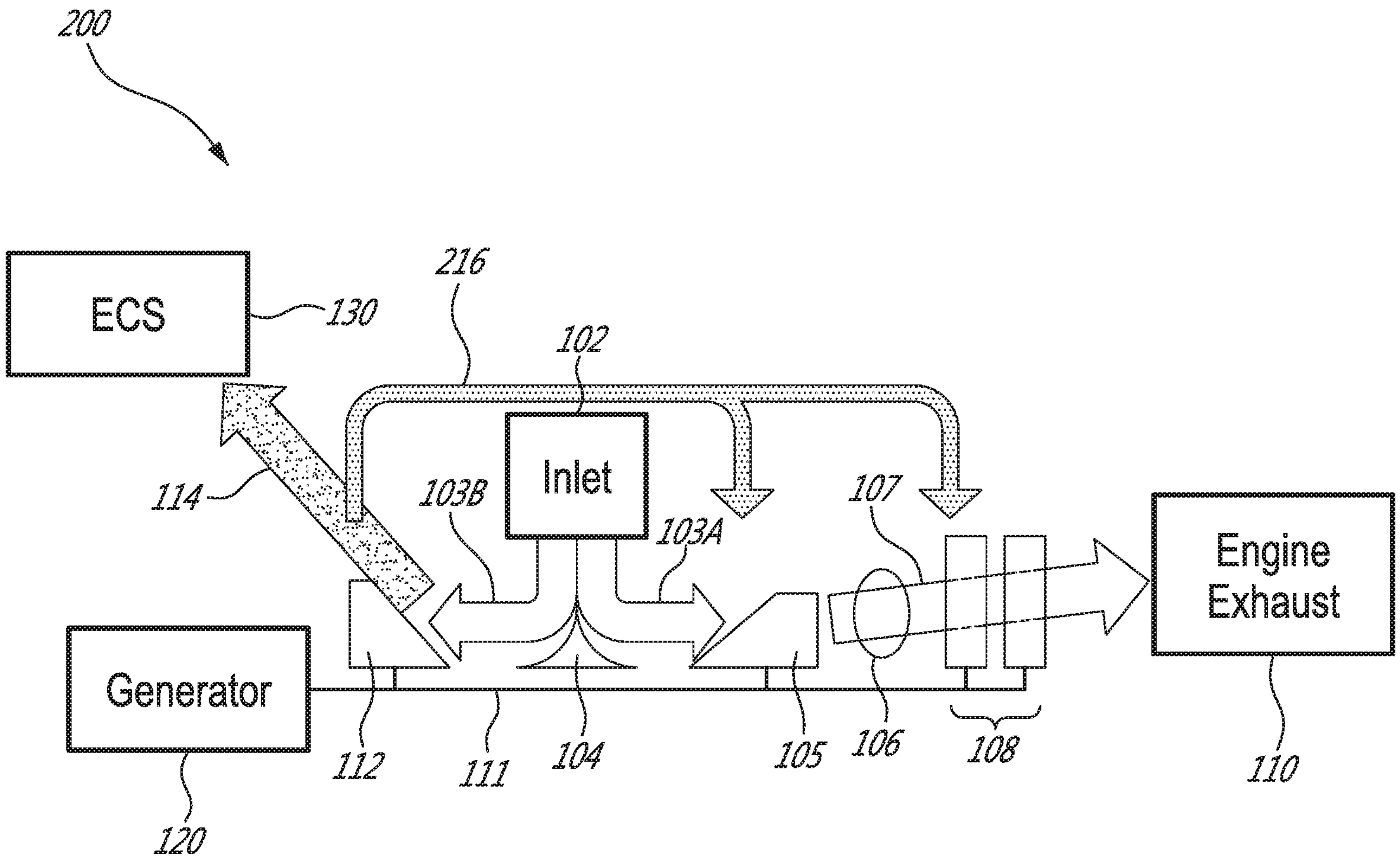
ECS
Inlet
Engine
Exhaust
Generator

FIG. 2

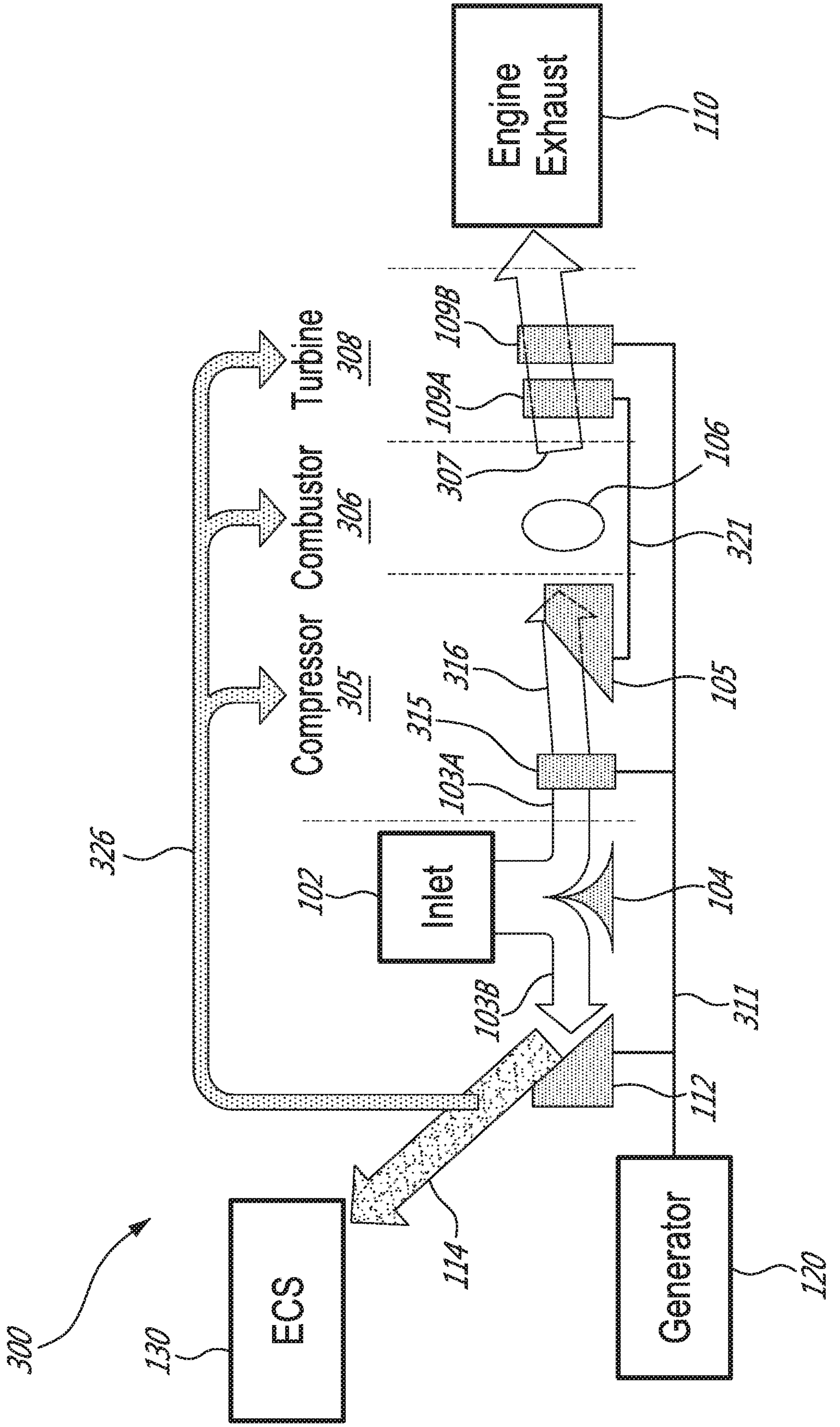
Engine Exhaust
Turbine
Combustor
Compressor
Inlet
ECS
Generator

FIG. 3

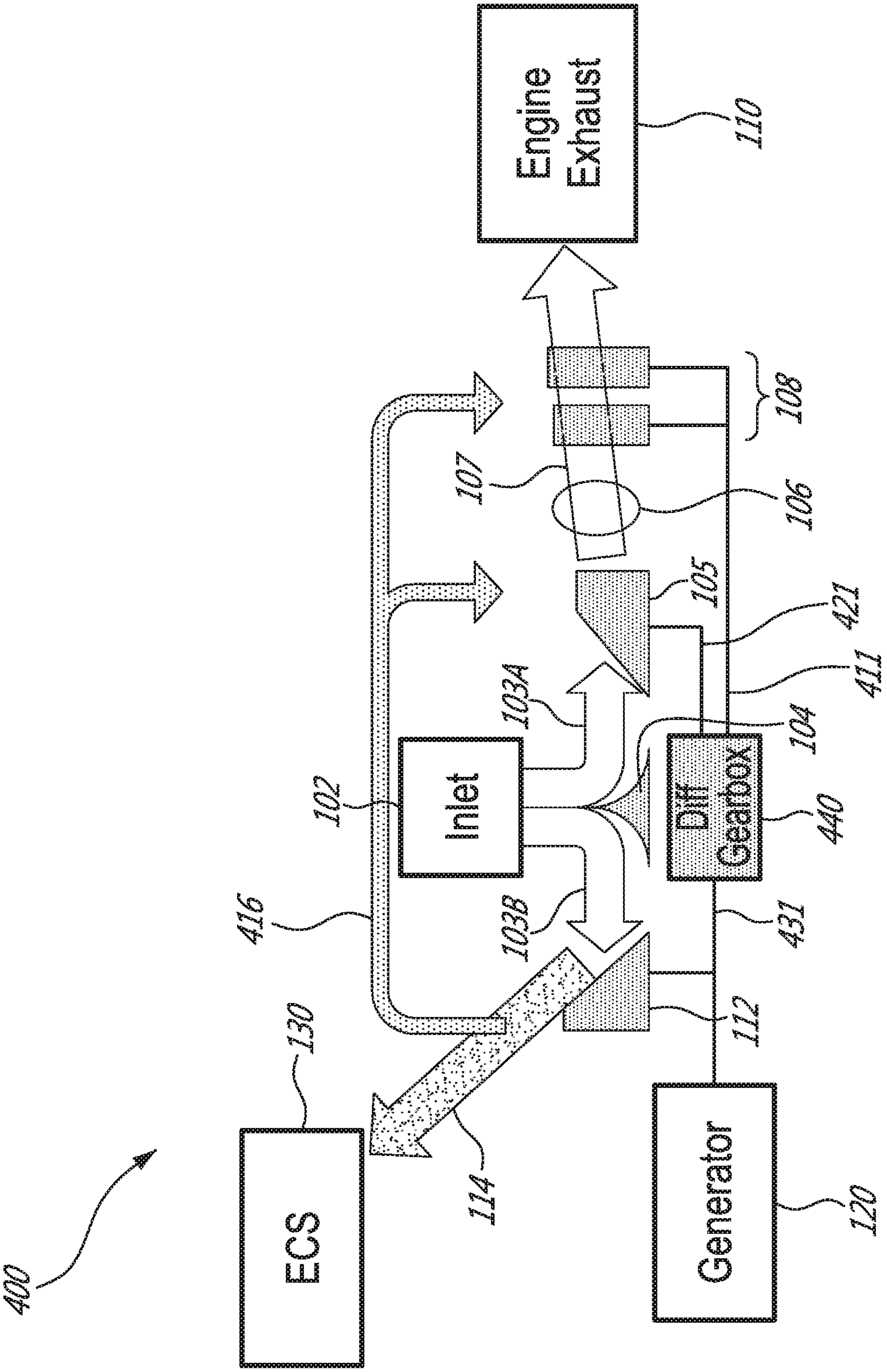
Engine Exhaust
Inlet
Diff Gearbox
ECS
Generator

FIG. 4

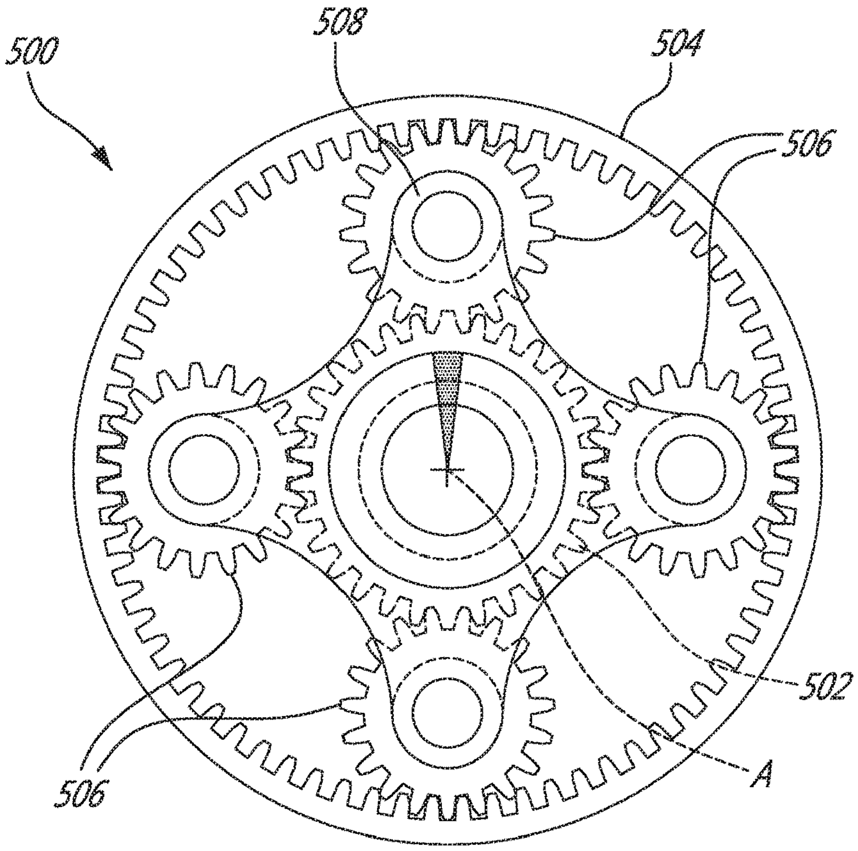

FIG. 5A

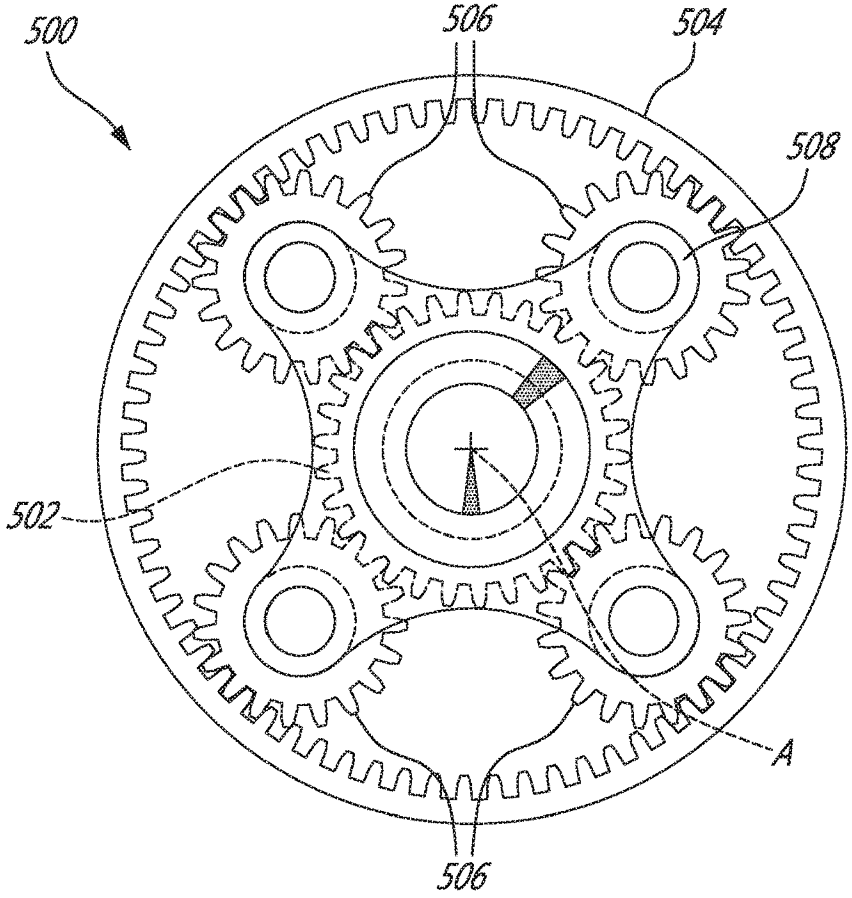

FIG. 5B

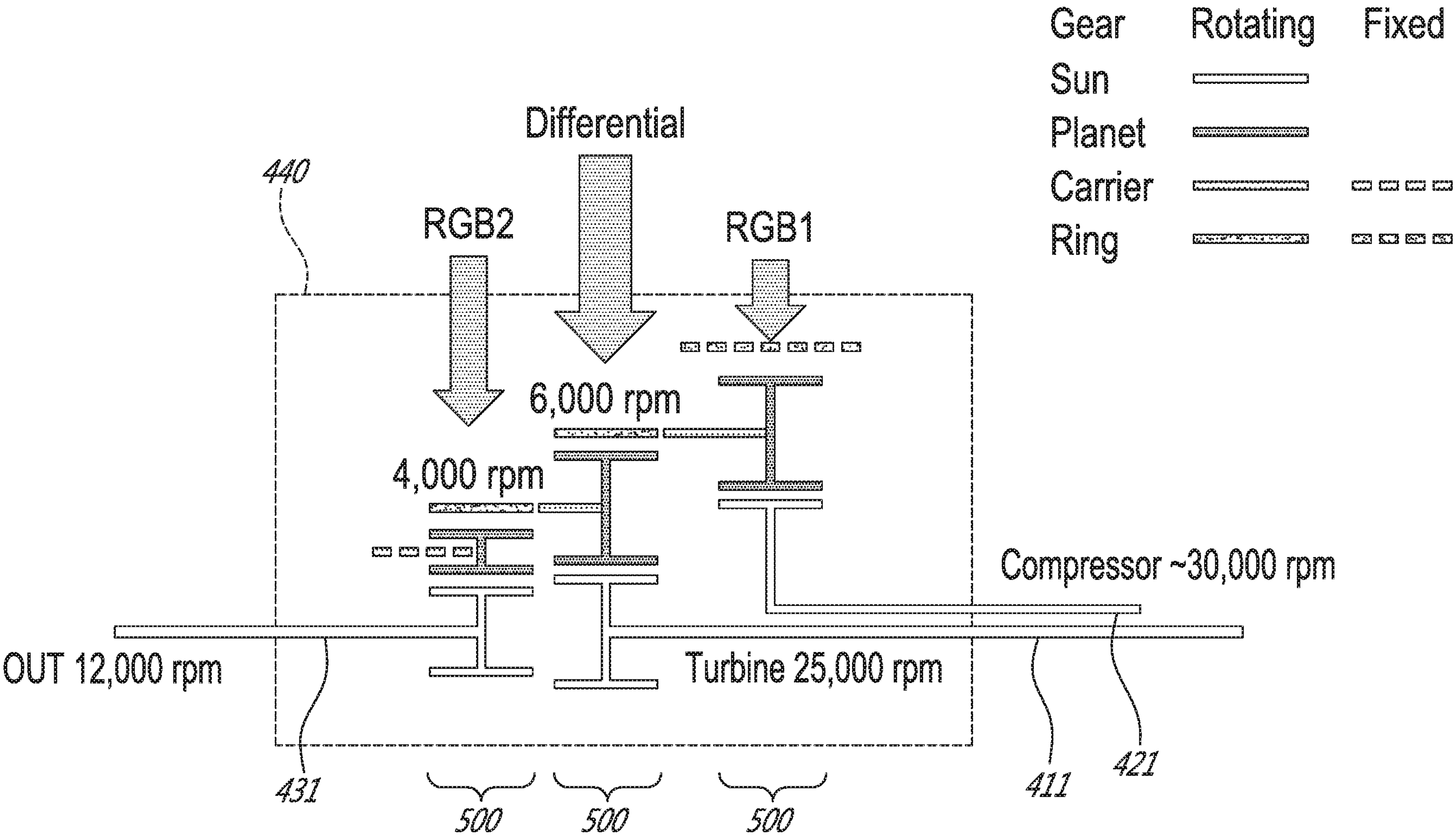
Gear
Rotating
Fixed
Sun
Planet
Carrier
Ring
Differential
440
RGB2
RGB1
6,000 rpm
4,000 rpm
Compressor ~30,000 rpm
OUT 12,000 rpm
Turbine 25,000 rpm
431
500
500
500
411
421

FIG. 6

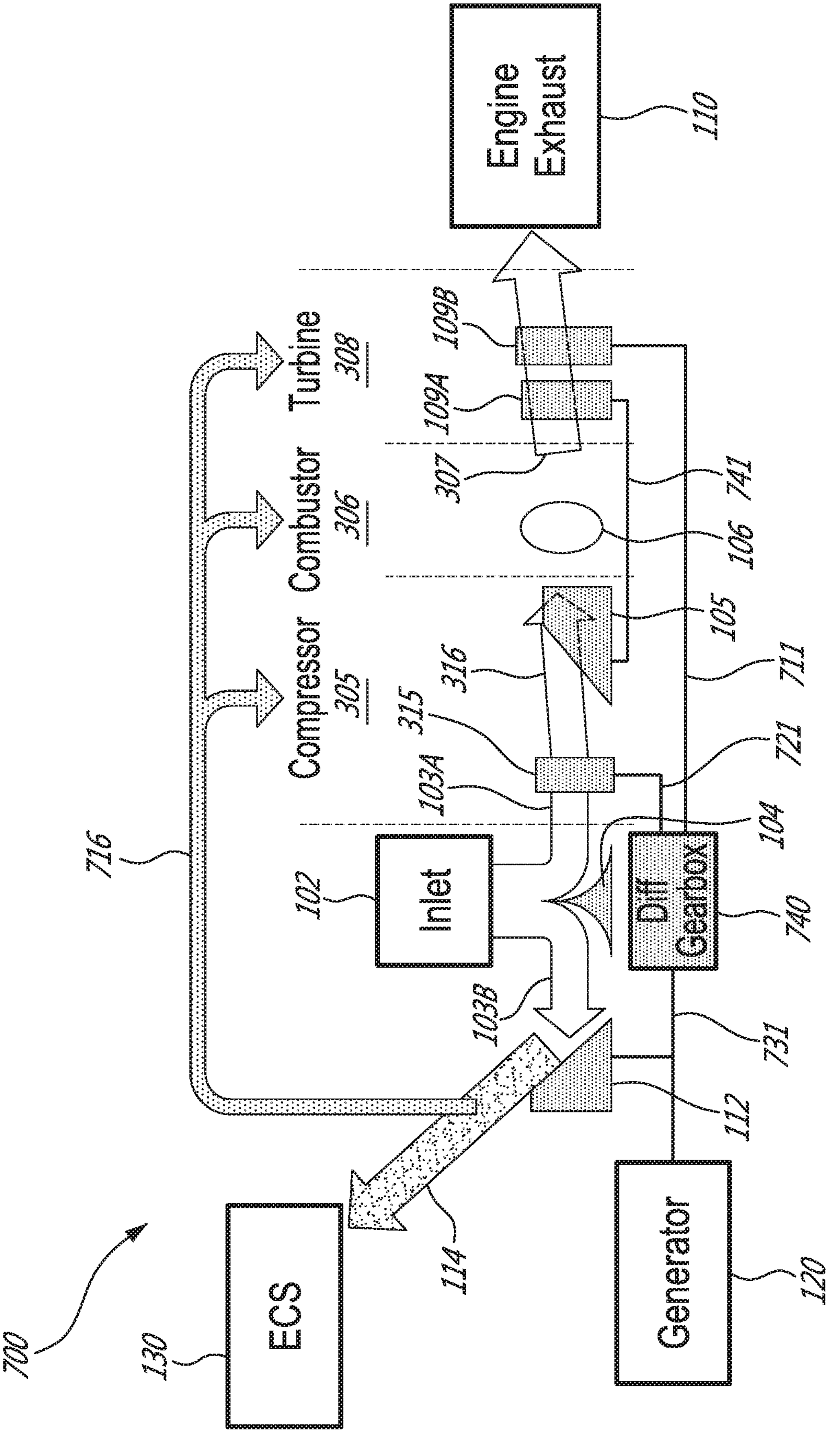
Engine Exhaust
Turbine
Combustor
Compressor
Inlet
Diff Gearbox
ECS
Generator

FIG. 7A

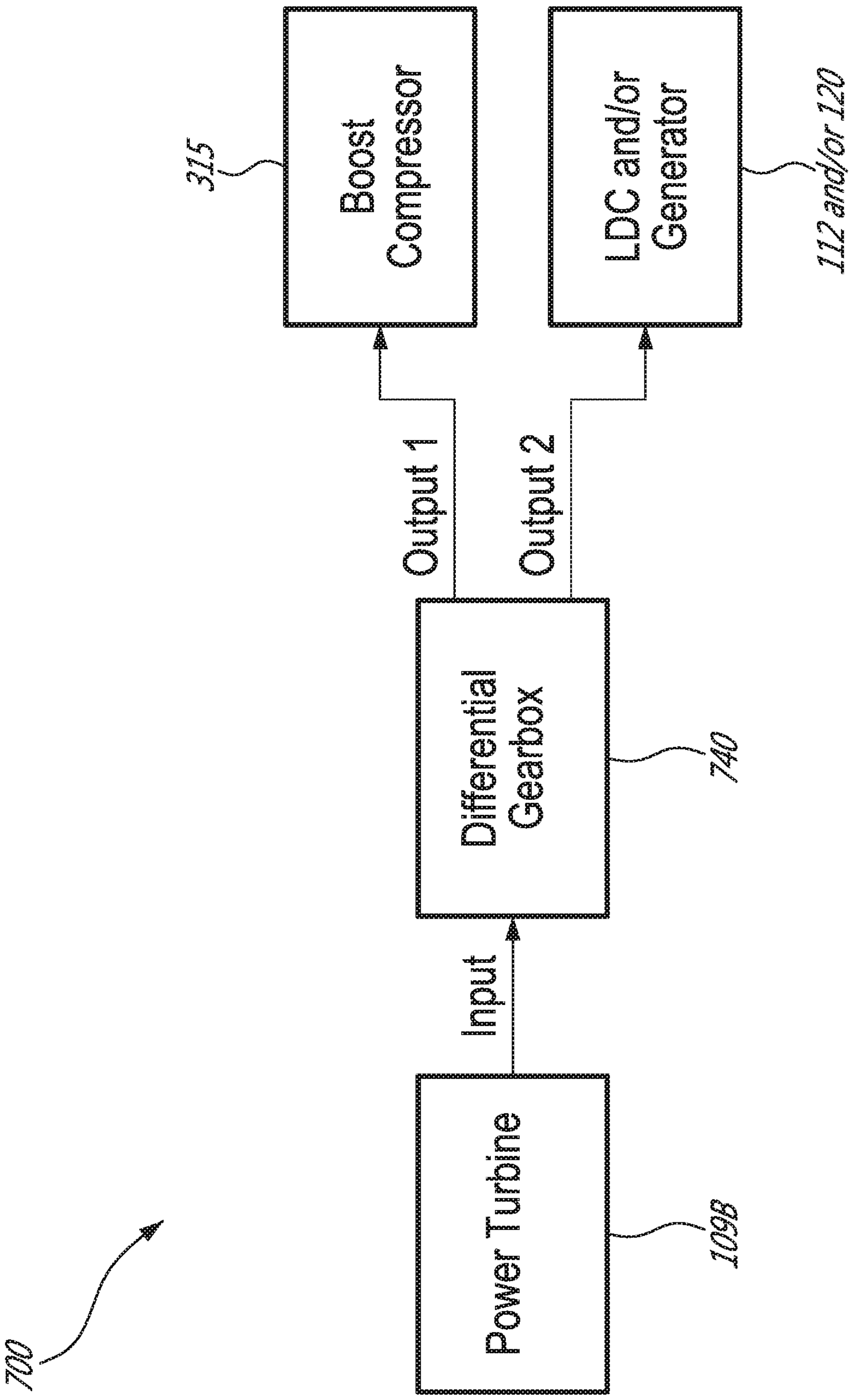
700
Power Turbine
109B
Input
Differential Gearbox
740
Output 1
Output 2
Boost Compressor
315
LDC and/or Generator
112 and/or 120

FIG - 7B

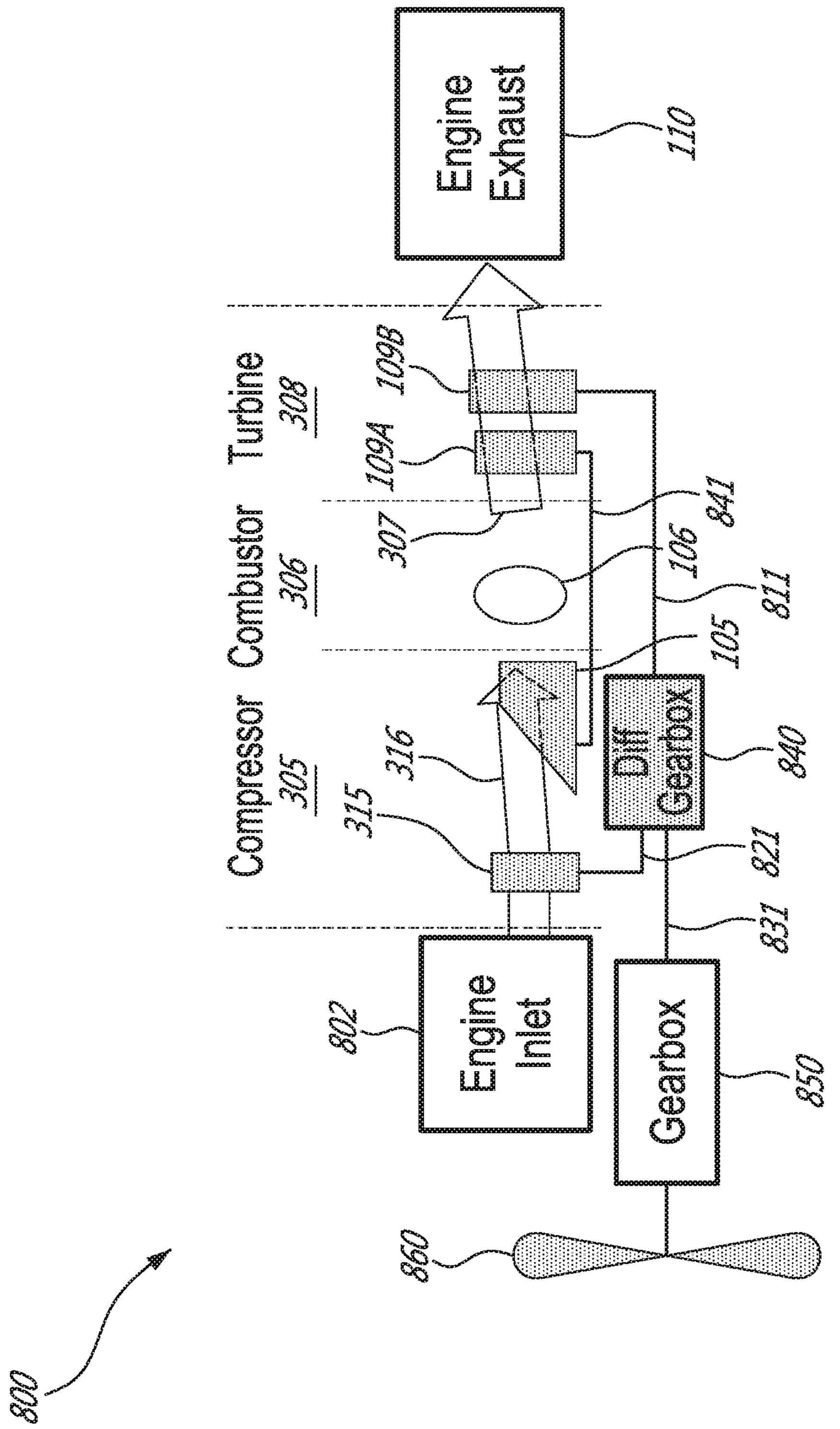
Engine Exhaust
Turbine
Combustor
Compressor
Diff Gearbox
Engine Inlet
Gearbox

FIG. 8

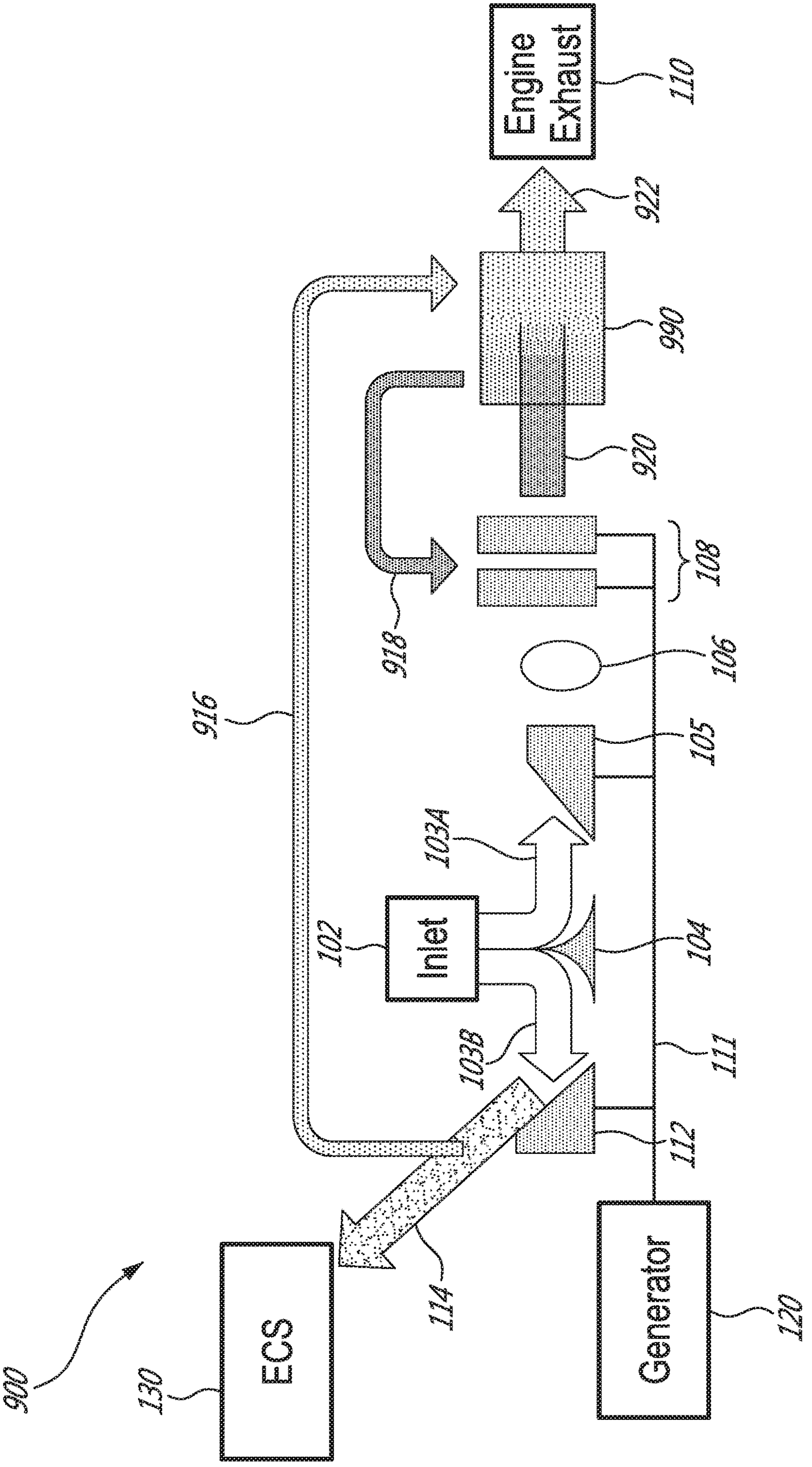
ECS
Generator
Inlet
Engine Exhaust

FIG-9

GAS TURBINE ENGINE WITH DIFFERENTIAL GEARBOX

FIELD

This relates to gas turbine engines and auxiliary power units.

BACKGROUND

In a conventional auxiliary power unit (APU) (or Auxiliary Power System (APS)) including a gas turbine engine, a load compressor (LDC) provides an air flow to an environmental control system (ECS). As the LDC may be mechanically linked to an electric generator that is also driven by the gas turbine engine, the components are constrained to a single speed. Therefore, the LDC may not stop rotating and the air flow generated by the LDC may never be reduced to zero. Unused air may be dumped into an exhaust stream, thereby wasting compressor work. Improvement is desirable.

SUMMARY

According to an aspect, there is provided an auxiliary power unit including: a load compressor configured to generate compressed air for an environmental control system of an aircraft; a gas turbine engine drivingly coupled to the load compressor; and a conduit establishing fluid communication between the load compressor and an injection location in a gas path of the gas turbine engine to direct at least some of the compressed air generated by the load compressor to the injection location, the injection location being upstream of a turbine of the gas turbine engine.

In some embodiments, a spool of the gas turbine engine is operatively coupled for common rotation with the load compressor.

In some embodiments, the injection location in the gas path is in a turbine section of the gas turbine engine.

In some embodiments, the injection location in the gas path is in a compressor section of the gas turbine engine.

In some embodiments, a spool of the gas turbine engine drives the load compressor and the load compressor rotates at a different speed from the spool.

In some embodiments, a differential gearbox is operatively coupled between the load compressor and the gas turbine engine.

In some embodiments, the injection location in the gas path is at a lower pressure than a pressure of the compressed air.

In some embodiments, an exhaust pathway establishes fluid communication between the load compressor and an exhaust of the gas turbine engine to direct at least some of the compressed air generated by the load compressor to the exhaust of the gas turbine engine.

In some embodiments, a recuperator is downstream of the gas turbine engine, and the conduit passes through the recuperator between the load compressor and the injection location.

In some embodiments, the recuperator is to provide heat exchange between exhaust of the gas turbine engine and at least some of the compressed air generated by the load compressor.

According to an aspect, there is provided a method of operating an auxiliary power unit of an aircraft, the method including: generating, by a load compressor drivingly coupled to a gas turbine engine, compressed air for an environmental control system of the aircraft; and directing at least some of the compressed air to an injection location in a gas path of the gas turbine engine, the injection location being upstream of a turbine of the gas turbine engine.

In some embodiments, the method further includes driving the load compressor with a spool of the gas turbine engine operatively coupled to the load compressor.

In some embodiments, the injection location in the gas path is in a turbine section of the gas turbine engine.

In some embodiments, the injection location in the gas path is in a compressor section of the gas turbine engine.

In some embodiments, the method further includes driving the load compressor with a spool of the gas turbine engine where the load compressor rotates at a different speed from the spool.

In some embodiments, the method further includes driving the load compressor with a spool of the gas turbine engine via a differential gearbox.

In some embodiments, the injection location in the gas path is at a lower pressure than a pressure of the compressed air.

In some embodiments, the method further includes directing at least some of the compressed air to an exhaust of the gas turbine engine.

In some embodiments, the method further includes performing a heat exchange between an exhaust of the gas turbine engine and the at least some of the compressed air, prior to directing the at least some of the compressed air to the injection location.

In some embodiments, the method further includes directing the at least some of the compressed air to a recuperator to perform the heat exchange.

According to another aspect, there is provided a gas turbine engine system, including: a boost compressor configured to compress air; a combustor in which the compressed air is mixed with fuel and ignited to generate a stream of combustion gases; and a turbine configured to extract energy from the combustion gases, the turbine being drivingly coupled to the boost compressor and to an output shaft via a differential gearbox configured to apportion an input torque from the turbine between a first output torque applied to the output shaft and a second output torque applied to the boost compressor.

In some embodiments, the first output torque is different from the second output torque.

In some embodiments, a rotational speed ratio between the output shaft and the turbine is different from a rotational speed ratio between the boost compressor and the turbine.

In some embodiments, the output shaft is drivingly coupled to a load compressor configured to generate compressed air for an environmental control system of an aircraft.

In some embodiments, the output shaft is also drivingly coupled to an electric generator.

In some embodiments, the output shaft is drivingly coupled to an electric generator.

In some embodiments, the gas turbine engine system further includes: a load compressor drivingly coupled to the output shaft and configured to generate compressed air for an environmental control system of an aircraft; and a conduit establishing fluid communication between the load compressor and an injection location in a gas path of the gas turbine engine to direct at least some of the compressed air generated by the load compressor to the injection location, the injection location being upstream of the turbine of the gas turbine engine.

In some embodiments, the gas turbine engine system further includes: a recuperator downstream of the gas turbine engine to provide heat exchange between exhaust of the gas turbine engine and at least some of the compressed air generated by the load compressor, and the conduit passes through the recuperator between the load compressor and the injection location.

In some embodiments, the output shaft is drivingly coupled to a propeller via a reduction gearbox.

In some embodiments, the differential gearbox includes an epicyclic gear set.

In some embodiments, the boost compressor is drivingly coupled to the differential gearbox via a first reduction gearbox.

In some embodiments, the output shaft is drivingly coupled to the differential gearbox via a second reduction gearbox.

In some embodiments, the differential gearbox includes a compound epicyclic gear set.

In some embodiments, the differential gearbox includes a first epicyclic gear set having a first sun gear rotatable about a first axis, a first ring gear rotatable about the first axis, one or more first planet gears, and a first carrier rotatable about the first axis; and the gas turbine engine system further includes: a second epicyclic gear set having a second sun gear rotatable about a second axis, a second ring gear rotatable about the second axis, one or more second planet gears, and a second carrier rotatable about the second axis; and a third epicyclic gear set having a third sun gear rotatable about a third axis, a third ring gear rotatable about the third axis, one or more third planet gears, and a third carrier rotatable about the third axis; and: the first sun gear is drivingly coupled to the boost compressor, the first ring gear is fixed, the first carrier ring is drivingly coupled to the second ring gear, the second sun gear is drivingly coupled to the turbine, the second carrier is drivingly coupled to the third ring gear, the third sun gear is drivingly coupled to the output shaft, and the third carrier ring is fixed.

According to another aspect, there is provided a method of operating a gas turbine engine, including: using a boost compressor to compress air; generating a stream of combustion gases by igniting the compressed air mixed with fuel; and extracting energy from the combustion gases with a turbine; and using a differential gearbox to apportion an input torque from the turbine between a first output torque applied to an output shaft and a second output torque applied to the boost compressor.

In some embodiments, the second output torque delivered to the boost compressor is different from the first output torque delivered to the output shaft.

In some embodiments, a torque split between the second output torque delivered to the boost compressor and the first output torque delivered to the output shaft is a constant ratio determined by a gear ratio of the differential gearbox.

In some embodiments, the gear ratio of the differential gearbox is the gear ratio between a sun gear and a ring gear of an epicyclic differential gear in the differential gearbox.

In some embodiments, the method further includes driving a propeller via the output shaft.

In some embodiments, the method further includes driving a load compressor via the output shaft.

In some embodiments, the method further includes driving a generator via the output shaft.

In some embodiments, the method further includes driving a load compressor and a generator via the output shaft.

In some embodiments, the method further includes directing at least some compressed air generated by the load compressor to an injection location in a gas path of the gas turbine engine, the injection location being upstream of the turbine.

In some embodiments, the method further includes performing a heat exchange between an exhaust of the gas turbine engine and the at least some of the compressed air, prior to directing the at least some of the compressed air to the injection location.

In some embodiments, the method further includes directing the at least some of the compressed air to a recuperator to perform the heat exchange.

In some embodiments, the method further includes directing at least some compressed air generated by the load compressor to an injection location in a gas path of the gas turbine engine, the injection location being in a turbine section of the gas turbine.

In some embodiments, the method further includes directing at least some compressed air generated by the load compressor to an injection location in a gas path of the gas turbine engine, the injection location being in a compressor section of the gas turbine.

Other features will become apparent from the drawings in conjunction with the following description.

BRIEF DESCRIPTION OF DRAWINGS

In the figures which illustrate example embodiments,

FIG. **1** is a schematic cross-section view of an auxiliary power unit;

FIG. **2** is a schematic cross-section view of an auxiliary power unit in which excess load compressor air is directed to a gas path of a gas turbine engine, in accordance with an embodiment;

FIG. **3** is a schematic cross-section view of an auxiliary power unit including a boost compressor and in which a high-pressure shaft of an engine core is separately rotatable from a power shaft in accordance with an embodiment;

FIG. **4** is a schematic cross-section view of an auxiliary power unit in which components are connected through a differential gearbox, in accordance with an embodiment; and

FIG. **5**A is a schematic diagram of an epicyclic (differential) gear set in a first position, in accordance with an embodiment;

FIG. **5**B is a schematic diagram of the epicyclic (differential) gear set of FIG. **5**A in a second position;

FIG. **6** is a schematic diagram of a differential gearbox, in accordance with an embodiment;

FIG. **7**A is a schematic cross-section view of an auxiliary power unit including a boost compressor and in which components are connected through a differential gearbox, in accordance with an embodiment;

FIG. **7**B is a schematic diagram of an operating environment of the differential gearbox of the auxiliary power unit of FIG. **7**A, in accordance with an embodiment;

FIG. **8** is a schematic cross-section view of a turboprop engine, in accordance with an embodiment; and

FIG. **9** is a schematic cross-section view of an auxiliary power unit in which excess load compressor air is directed to a recuperator.

DETAILED DESCRIPTION

FIG. **1** illustrates an auxiliary power unit (APU) **100** (sometimes called “auxiliary power system”) including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power. Any other suitable engine may be employed.

As shown in FIG. **1**, APU **100** includes an inlet **102** through which ambient air is drawn, a flow splitter **104** for splitting the inlet air into a engine stream air **103**A and a load stream air **103**B, a high pressure compressor (HPC) **105** for pressurizing the engine stream air **103**A, a combustor **106** in which the compressed engine stream air **103**A is mixed with fuel and ignited for generating an annular combustion stream **107** of hot combustion gases, and a turbine section **108** having turbines, for example, a two-stage turbine as shown in FIG. **1** or other multi-stage turbine, for extracting energy from the combustion gases which then exhaust to engine exhaust **110**. The HPC **105**, combustor **106** and turbine section **108** form part of the gas turbine engine portion of the APU **100**. The gas turbine engine defines a gas path through which gases flow, such as engine stream air **103**A and combustion stream **107**, to drive the engine. A power shaft **111** is connected to one or more turbines of turbine section **108** and HPC **105**. Power shaft **111** is driven by the one or more turbines of turbine section **108**.

APU **100** further includes a load compressor (LDC) **112** for pressurizing the load stream air **1038** to generate load compressor air **114** for use by an environment control system (ECS) **130** of an aircraft in which APU **100** is installed. In some embodiments, for example, as shown in FIG. **1**, LDC **112** may be linked mechanically to HPC **105** and turbine section **108** of the gas turbine engine by way of power shaft **111**, and thus LDC **112** may be drivingly coupled to the gas turbine engine. APU **100** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the engine exhaust for directing at least some of excess load compressor air **116** to, in an example, an exhaust pathway to engine exhaust **110**. Alternatively or in addition as explained below, the excess load compressor air **116** may be directed to another location upstream of one or more turbines of turbine section **108** in order to permit energy from the excess load compressor air **116** to be converted into useful work by the gas turbine engine of APU **100**.

ECS **130** may provide air supply, thermal control, and cabin pressurization in the aircraft.

APU **100** may also be adapted to supply electric power to aircraft systems by way of a generator **120**. Generator **120** may by an oil-cooled generator and include a gearbox for transferring power from power shaft **111** of APU **100** to electric power. In an example, generator **120** may operate at a constant speed of approximately 12,000 rpm (revolutions per minute), plus or minus 500 rpm.

In use, inlet **102** draws air into APU **100**, and flow splitter **104** splits the inlet air into engine stream air **103**A and load stream air **1038**.

Engine stream air **103**A is directed to HPC **105**. HPC **105** pressurizes the air by rotating. In combustor **106**, the compressed engine stream air **103**A is mixed with fuel and ignited, generating combustion stream **107** of hot combustion gases. Propulsion of combustion stream **107** through turbine section **108** rotates the turbines of turbine section **108**, thus extracting energy from the combustion gases, and rotating power shaft **111** that is drivingly coupled to one or more turbines in turbine section **108**. Combustion stream **107** then exits APU **100** as engine exhaust **110**.

Load stream air **1038** is directed to LDC **112**. In embodiments in which LDC **112** is linked mechanically to HPC **105** and turbine section **108**, for example, by way of power shaft **111**, rotation of power shaft **111** drives the rotation of LDC **112**.

The rotation of LDC **112** compresses air within LDC **112**, generating compressed load compressor air **114**. The compressed load compressor air **114** may then be directed to ECS **130** of the aircraft. As such, APU **100** is adapted to supply load compressor air **114** for pneumatic power to ECS **130**.

Load compressor air **114** generated by LDC **112** may be regulated by inlet guide vanes and bleed valves (not shown). However, since the rotation of LDC **112** is mechanically linked to HPC **105**, as HPC **105** rotates, so does LDC **112**. In some embodiments, LDC **112** and HPC **105** rotate at the same speed. In some embodiments, LDC **112** and HPC **105** rotate at different speeds.

Thus, in embodiments in which LDC **112** is mechanically linked to HPC **105**, any time HPC **105** rotates LDC **112** will generate load compressor air **114**. As shown in FIG. **1**, if more load compressor air **114** is generated by LDC **112** than is required by ECS **130**, unused excess load compressor air **116** may be released by a bleed valve (not shown) and directed along an exhaust pathway to be injected into engine exhaust **110**. As such, compressor work (generated by HPC **105** and LDC **112**) may be wasted.

Rotation of power shaft **111** may also transfer power to the gearbox of generator **120** for electric power.

The sizing of APU **100** may be determined by the requirements at the highest commanded generator **120** power and/or ECS **130** pneumatic power, leaving APU **100** running below its maximum power at other points of the operating envelope.

FIG. **2** illustrates an auxiliary power unit (APU) **200** including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power, in which excess load compressor air is directed to HPC **105** and turbine section **108**. Any other suitable engine may be employed.

As shown in FIG. **2**, APU **200** includes some of the same structure and components as the architecture of APU **100**, including inlet **102**, flow splitter **104**, engine stream air **103**A, load stream air **1038**, compressor **105**, combustor **106**, combustion stream **107**, turbine section **108**, engine exhaust **110**, power shaft **111**, LDC **112**, load compressor air **114**, generator **120** and ECS **130**, as described herein.

HPC **105**, combustor **106** and turbine section **108** form part of the gas turbine engine portion of the APU **200**. The gas turbine engine defines a gas path through which gases, such as engine stream air **103**A and combustion stream **107** flow.

APU **200** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the gas path of the gas turbine engine, in combination with a controller and one or more bypass valves for controlling and directing the flow of excess load compressor air **216** generated by LDC **112**. In some embodiments, APU **200** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the engine exhaust for directing at least some of excess load compressor air **216** to, in an example, an exhaust pathway to engine exhaust **110**.

In use, in embodiments in which LDC **112** of APU **200** is mechanically linked to HPC **105**, any time HPC **105** rotates LDC **112** will generate load compressor air **114**.

As shown in FIG. **2**, if more load compressor air **114** is generated by LDC **112** than is required by ECS **130**, unused excess load compressor air **216** may be released by a bleed valve (not shown) and directed to be injected into the gas path of the gas turbine engine upstream of a turbine of the gas turbine engine, for example, in HPC **105**.

As also shown in FIG. **2**, excess load compressor air **216** may be directed along an excess air pathway to be injected, for example, adjacent one or more turbines in turbine section **108**. Injection of excess load compressor air **216** into turbine section **108** may assist in the rotation of one or more turbines of turbine section **108** and permit energy from the excess load compressor air **216** to be converted into useful work by turbine section **108**.

In some embodiments, excess load compressor air **216** may be directed along an excess air pathway to be injected at combustor **106** and/or any of the stages of compression upstage of combustor **106**. In some embodiments, at least some of excess load compressor air **216** may be directed along an exhaust pathway to be injected into engine exhaust **110**.

Excess load compressor air **216** may be directed along an excess air pathway to be injected at an area of lower pressure than load compressor air **114** within APU **200**. Thus, backflow of excess load compressor air **216** may be avoided.

In some embodiments, a detector may detect the load/demand for load compressor air **114** required by ECS **130**, and used to redirect load compressor air **114** and excess load compressor air **216** as needed.

In some embodiments, redirection of excess load compressor air **216** may be retrofitted on an existing gas turbine engine or APU.

Conveniently, redirecting excess load compressor air **216** into the gas path of the turbine of APU **200** (e.g., at one or more locations such as turbine section **108**, combustor **106** and HPC **105**) may take advantage of the work applied to load compressor air **114** and may improve the overall performance of APU **200**.

FIG. **3** illustrates an auxiliary power unit (APU) **300** including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power, in which a spool of the engine core of the gas turbine engine, including HPC **105**, combustor section **306** and high-pressure turbine (s) **109**A, is separately rotatable from the power shaft **311**, with additional compressor(s) added. Any other suitable engine may be employed.

As shown in FIG. **3**, APU **300** includes some of the same structure and components as the architecture of APU **100**, including inlet **102**, flow splitter **104**, engine stream air **103**A, load stream air **103**B, HPC **105**, engine exhaust **110**, load compressor **112**, load compressor air **114**, generator **120** and ECS **130**, as described herein.

As shown in FIG. **3**, APU **300** includes a compressor section **305** for pressurizing the engine stream air **103**A, in which engine stream air **103**A is compressed by boost compressor **315** to form boosted compressor stream **316** which is then further compressed by HPC **105** to form further compressed air, a combustor section **306** in which the further compressed air is mixed with fuel and ignited for generating an annular combustion stream **307** of hot combustion gases, and a turbine section **308** having high-pressure turbine **109**A and power turbine **109**B for extracting energy from the combustion gases which then exhaust to engine exhaust **110**.

Compressor section **305**, combustor section **306** and turbine section **308** form part of the gas turbine engine portion of APU **300**. The gas turbine engine defines a gas path through which gases flow, such as engine stream air **103**A, boosted compressor stream **316** and combustion stream **307**.

Compressor section **305** includes a boost compressor **315**, for pressurizing engine stream air **103**A to generate a boosted compressor stream **316**, or compressed air, directed toward HPC **105** for further compression to form further compressed air. Boost compressor **315** may have variable geometry inlet guide vanes and/or handling bleed valves to manage its surge margins. Accordingly, boost compressor **315** may be disposed upstream of HPC **105**. In some embodiments, boost compressor **315** may be separately rotatable from high-pressure shaft **321** and consequently also separately rotatable from HPC **105**.

In some embodiments, combustor section **306** includes combustor **106**, as described herein. In some embodiments, combustion stream **307** may be combustion stream **107**, as described herein.

In some embodiments, turbine section **308** includes one or more turbines connected to HPC **105** by way of a high-pressure shaft **321**, referred to herein as "high-pressure turbine **109**A", and one or more turbines connected to LDC **112** by way of a power shaft **311**, referred to herein as "power turbine **109**B". In some embodiments, turbine section **308** may be generally similar to turbine section **108**, as described herein.

As shown in FIG. **3**, in some embodiments, LDC **112** may be linked mechanically to boost compressor **315** and power turbine **1098** by way of a power shaft **311**. In some embodiments, HPC **105** and high-pressure turbine **109**A may be mechanically linked together by way of a high-pressure shaft **321**.

In some embodiments, high-pressure shaft **321** may be separate and independent from power shaft **311**. This may reduce a need for inlet guide vanes and bleed valves for boost compressor **315**. Furthermore, high-pressure shaft **321** may not be constrained to a fixed input speed of generator **120**.

FIG. **3** illustrates an example of an APU having a dual-spool configuration. For example, the gas turbine engine may include a high-pressure spool including high-pressure shaft **321**, one or more stages of multistage compressor section **305** such as HPC **105**, and one or more turbines of turbine section **308** such as high-pressure turbine **109**A. The gas turbine engine may also include a low-pressure spool including low-pressure power shaft **311** including one or more stages of multistage compressor section **305** such as boost compressor **315** and one or more turbines of turbine section **308** such as power turbine **1098**. It is understood that the gas turbine engine of APU **300** may not be limited to such a dual-spool configuration.

In some embodiments, APU **300** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the gas path of the gas turbine engine, in combination with a controller and one or more bypass valves for controlling and directing the flow of excess load compressor air **326** generated by LDC **112** (for example, excess load compressor air not required by ECS **130**).

Excess load compressor air **326** may be directed along an excess air pathway to be injected into the gas path of the gas turbine engine upstream of a turbine of the gas turbine engine, for example, adjacent one or more of high-pressure turbine **109**A and power turbine **1098** in turbine section **308**. Injection of excess load compressor air **326** into turbine section **308** may assist in the rotation of one or more of high-pressure turbine **109**A and power turbine **1098** of turbine section **308**. In some embodiments, excess load compressor air **326** may be injected upstream of power turbine **1098** and downstream of high-pressure turbine **109**A, which may constitute a location with lower pressure than upstream of high-pressure turbine **109**A.

In some embodiments, excess load compressor air **326** may be directed along an excess air pathway to be injected at combustor section **306** and/or any of the stages of compression upstage of combustor section **306**.

Excess load compressor air **326** may be directed along an excess air pathway to be injected at an area of lower pressure than load compressor air **114** within APU **300**, for example, upstream of power turbine **1098** and downstream of high-pressure turbine **109**A, as discussed above. Thus, backflow of excess load compressor air **326** may be avoided.

In some embodiments, a detector may detect the load of load compressor air **114** required by ECS **130**, and used to redirect load compressor air **114** and excess load compressor air **326** as needed.

Conveniently, redirecting excess load compressor air **326** into the gas path or power generation sections of APU **300** (such as compressor section **305**, combustor section **306** and turbine section **308**) may take advantage of the work applied to load compressor air **114** and may improve the overall performance of APU **300**.

Conveniently, the configuration of APU **300** may offer improved performance over the range of an APU operating envelope.

Additional engine components of APU **300** may add weight, expense and complexity and consideration to the design of an APU. Unlinking components from a single shaft (and single speed constraint), such as components LDC **112**, boost compressor **315**, power turbine **1098** unlinked from components HPC **105** and high-pressure turbine **109**A as shown in FIG. **3**, may allow components to operate within an efficient region of their operating range, while continuing to maintain a fixed speed for generator **120** input.

FIG. **4** illustrates an auxiliary power unit (APU) **400** including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power, in which components are connected through a differential gearbox. The differential gearbox can be configured to apportion an input torque between a first output torque and a second output torque.

Any other suitable engine may be employed.

As shown in FIG. **4**, APU **400** includes some of the same structure and components as the architecture of APU **100**, including inlet **102**, flow splitter **104**, engine stream air **103**A, load stream air **103**B, HPC **105**, combustor **106**, combustion stream **107**, turbine section **108**, engine exhaust **110**, LDC **112**, load compressor air **114**, generator **120** and ECS **130**, as described herein.

HPC **105**, combustor **106** and turbine section **108** form part of the gas turbine engine portion of APU **400**. The gas turbine engine defines a gas path through which gases flow, such as engine stream air **103**A and combustion stream **107**.

In place of a power shaft **111**, APU **400** may include a turbine shaft **411**, a compressor shaft **421** and a load shaft **431**. Turbine shaft **411** connects to one or more turbines of turbine section **108**. Compressor shaft **421** connects to HPC **105**. Load shaft **431** connects to LDC **112** and generator **120**.

Turbine shaft **411**, compressor shaft **421** and load shaft **431** are connected to a differential gearbox **440**. Differential gearbox **440** may have one input shaft and two output shafts, each of which may be connected through a reduction gear set. In some embodiments, turbine shaft **411** may provide rotational input or torque to differential gearbox **440**, and compressor shaft **421** and load shaft **431** may receive rotational output or torque from differential gearbox **440**.

In some embodiments, differential gearbox **440** may include a compound epicyclic gear set. Differential gearbox **440** may contain one or more interconnected epicyclic (differential) gears, for example, epicyclic planetary gear set **500**. Differential gearbox **440** may comprise three interconnected shafts, as described in further detail below. In some embodiments, differential gearbox **440** may be a fixed speed gearbox. In some embodiments, differential gearbox **440** may be a variable speed gearbox.

In some embodiments, APU **400** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the gas path of the gas turbine engine, in combination with a controller and one or more bypass valves for controlling and directing the flow of excess load compressor air **416** generated by LDC **112** (for example, excess load compressor air not required by ECS **130**).

Excess load compressor air **416** may be directed along an excess air pathway to be injected into the gas path of the gas turbine engine upstream of a turbine of the gas turbine engine, for example, adjacent one or more turbines of turbine section **108**. Injection of excess load compressor air **416** may assist in the rotation of one or more turbines of turbine section **108**.

In some embodiments, excess load compressor air **416** may be directed along an excess air pathway to be injected at combustor **106** and/or any of the stages of compression upstream of combustor **106**.

Excess load compressor air **416** may be directed along an excess air pathway to be injected at an area of lower pressure than load compressor air **114** within the engine portion of APU **400**. Thus, backflow of excess load compressor air **416** may be avoided.

In some embodiments, a detector may detect the load of load compressor air **114** required by ECS **130**, and used to redirect load compressor air **114** and excess load compressor air **416** as needed.

Conveniently, redirecting excess load compressor air **416** into the power generation sections of APU **400** (such as HPC **105**, combustor **106** and turbine section **108**) may take advantage of the work applied to load compressor air **114** and may improve the overall performance of APU **400**.

FIG. **5**A is a schematic of a planetary gear set **500** of differential gearbox **440** of APU **400** in a first position, in accordance with an embodiment. FIG. **5**B is a schematic of planetary gear set **500** of FIG. **5**A in a second position.

Planetary gear set **500** includes four components: a sun gear **502** located in the center, a ring gear **504** that is the outer annulus gear, planet gears **506** connecting the outside of sun gear **502** to the inside of ring gear **504**, and a carrier **508** that connects planet gears **506** at their centers of rotation. Sun gear **502**, ring gear **504** and carrier **508** all rotate about center of axis A of planetary gear set **500**.

In the second position illustrated in FIG. **5**B, carrier **508** is rotated 45 degrees clockwise and ring gear **504** is held fixed as compared to the first position illustrated in FIG. **5**A.

In some embodiments, differential gearbox **440** may include three planetary gear sets **500**, interconnected as shown schematically in FIG. **6**. Turbine shaft **411** may be connected to a sun gear **502** of a first planetary gear set **500** (labeled “Differential” in FIG. **6**), compressor shaft **421** may be connected to a sun gear **502** of a second planetary gear set **500** (labeled “RGB**1**” in FIG. **6**), and load shaft **431** may be connected to a sun gear **502** of a third planetary gear set **500** (labeled "RGB**2**" in FIG. **6**). In some embodiments, compressor shaft **421** may be connected to a ring gear **504** of a second planetary gear set **500** or a carrier **508** of a second planetary gear set **500**, depending on the speed of the component(s) driven by compressor shaft **421**. In some embodiments, load shaft **431** may be connected to a ring gear **504** of a third planetary gear set **500** or a carrier **508** of a third planetary gear set **500**, depending on the speed of the component(s) driven by load shaft **431**. "RGB**1**" and "RGB**2**" may operate as a reduction gear set. Reduction gears such as "RGB**1**" and "RGB**2**" may be fixed and may be used to scale up or down the rotational speed (revolutions per minute) that are output from the "Differential" gear set. In some embodiments, reduction gear sets or gearboxes may or may not be integral with "Differential" or disposed within differential gearbox **440**, or may be disposed in a separate location from the differential gear set or differential gearbox. In some embodiments, reduction gear sets or gearboxes may or may not be present. Reduction gear sets may or may not be planetary gear sets.

FIG. **6** illustrates the interconnection between carrier **508** of "RGB**1**" and ring gear **504** of "Differential", and the interconnection between carrier **508** of "Differential" and ring gear **504** of "RGB**2**". As noted in FIG. **6**, ring gear **504** of "RGB**1**" and carrier **508** of "RGB**2**" are fixed. The remaining components rotate.

In an example as shown in FIG. **6**, with appropriate gear ratios, one or more turbines of turbine section **108** may rotate turbine shaft **411** and sun gear **502** of "Differential" at 25,000 rpm, rotating ring gear **504** of "Differential" at 6,000 rpm, and thus rotating carrier **508** of "RGB**1**" at 6,000 rpm. Carrier **508** of "Differential" rotates at 4,000 rpm, thus rotating ring gear **504** of "RGB**2**" at 4,000 rpm. Reduction gear "RGB**1**" thereby rotates its sun gear **502** and thus compressor shaft **421** at 30,000 rpm, and reduction gear "RBG**2**" thereby rotates its sun gear **502** and thus load shaft **431** at 12,000 rpm. These speeds are provided for reference, and may not specifically refer to a particular design. Other suitable speed ranges may be contemplated.

Differential gearbox **440** may thus split power and torque between shafts (for example, turbine shaft **411**, compressor shaft **421** and load shaft **431**). Unlike a standard gear set that transfers power and reduces torque in a linear fashion, differential gearbox **440** may split power between shafts (for example, turbine shaft **411**, compressor shaft **421** and load shaft **431**) based on speed and gear ratio of sun gear(s) **502** and ring gear(s) **504** of gears **500** in differential gearbox **440**. Differential gearbox **440** may thus split torque between output shafts at a constant ratio that may be determined by a gear ratio such as the ratio of the sun gear to the ring gear, for example, in the "Differential" gear of FIG. **6**. In some embodiments, turbine shaft **411**, compressor shaft **421** and load shaft **431** may be interchanged between the gears described herein, depending on power split requirements. In an example, load shaft **431** may not run off carrier **508** of "Differential", and compressor shaft **421** may not run off ring gear **504** of "Differential".

APU **400** may thus be able to maintain a constant output shaft speed on load shaft **431** (in an example, 12,000 rpm), while increasing or decreasing compressor shaft **421** and turbine shaft **411** speeds as output power increases or decreases. Allowing compressor shaft **421** and turbine shaft **411** speeds to vary may allow each component to operate at a more effective region of its operating range, and may make APU **400** more efficient.

In some embodiments, differential gearbox **440** may include as few as one planetary (the "differential") with standard reduction gears on from one to three input/output shafts. In some embodiments, differential gearbox **440** may include as many as three additional epicyclic gear sets (four total) with or without additional RGBs. In some embodiments, differential gearbox **440** may include any other suitable combination of epicyclic and reduction gear sets.

FIG. **7**A illustrates an auxiliary power unit (APU) **700** including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power, in which components are connected through a differential gearbox. Any other suitable engine may be employed.

As shown in FIG. **7**A, APU **700** includes some of the same structure and components as the architecture of APU **300**, as described herein, including inlet **102** through which ambient air is drawn, flow splitter **104** for splitting the inlet air into a engine stream air **103**A and a load stream air **103**B. APU **700** further includes compressor section **305** for pressurizing the engine stream air **103**A by way of boost compressor **315**, forming boosted compressor stream **316** for further compression by HPC **105** to form further compressed air and then fed to combustor section **306**. Combustor section **306** may include, for example, combustor **106**, and compressed air is mixed with fuel and ignited for generating an annular combustion stream **307** of hot combustion gases. Turbine section **308** has high-pressure turbine **109**A and power turbine **109**B for extracting energy from the combustion gases which then exhaust to engine exhaust **110**.

Compressor section **305**, combustor section **306** and turbine section **308** form part of the gas turbine engine, of which HPC **105**, combustor section **306** and high-pressure turbine **109**A form an engine core. The gas turbine engine defines a gas path through which gases flow, such as engine stream air **103**A, boosted compressor stream **316** and combustion stream **307**.

APU **700** further includes LDC **112** for pressurizing load stream air **103**B to generate load compressor air **114** for use by ECS **130**. In some embodiments, APU **700** may not include a load compressor such as LDC **112**.

APU **700** may include a turbine shaft **711**, a boost compressor shaft **721**, a load shaft **731** and an engine core shaft **741**. Turbine shaft **711** connects to power turbine **109**B of turbine section **308**. Boost compressor shaft **721** connects to boost compressor **315**. Load shaft **731** connects to LDC **112** and generator **120**. In some embodiments, APU **700** may not include a generator such as generator **120**.

As shown in FIG. **7**A, turbine shaft **711**, and engine core shaft **741** may be mechanically uncoupled, for example, in a dual spool configuration, and therefore may permit separate rotation. Thus, HPC **105** and high-pressure turbine **109**A may be mechanically uncoupled from power turbine **109**B, and therefore may permit separate rotation.

Turbine shaft **711**, boost compressor shaft **721** and load shaft **731** are connected to differential gearbox **740**. In some embodiments, differential gearbox **740** may have similar or the same structure and components as differential gearbox **440**, or other suitable differential gearbox. Differential gearbox **740** may differ from differential gearbox **440** by having input from power turbine **109**B by way of turbine shaft **711** instead of one or more turbines of turbine section **108** connected to a turbine shaft **411** as shown in FIG. **4**.

In a similar manner to the configuration of APU **300** shown in FIG. **3**, as illustrated in FIG. **7**A, the gas turbine engine of APU **700** may have a dual-spool configuration but it is understood that the gas turbine engine may not be limited to such configuration.

FIG. 7B is a schematic diagram of the operating environment of differential gearbox **740** in APU **700**. As seen in FIG. 7B, Input of torque to differential gearbox **740** may be from the rotation of power turbine **109**B, for example, by way of turbine shaft **711**. Output 1 of torque from differential gearbox **740** may rotate boost compressor **315**, for example, by way of boost compressor shaft **721**. Output 2 of torque from differential gearbox **740** may rotate LDC **112** and/or generator **120**, for example, by way of load shaft **731**.

Optionally, Input, Output 1 and Output 2 from differential gearbox **740** may be passed through reduction gears (for example, "RGB**1**" and "RBG**2**" as shown in FIG. **6**) to scale each of the outputs to a desired revolutions per minute to transfer to boost compressor **315**, for example, by way of boost compressor shaft **721**, and LDC **112** and generator **120**, for example, by way of load shaft **731**.

Returning to FIG. 7A, engine core shaft **741** connects HPC **105** with high-pressure turbine **109**A.

The component configuration shown in FIG. 7A, in particular the use of differential gearbox **740**, may allow boost compressor shaft **721**, load shaft **731** and engine core shaft **741** to rotate at more effective speeds.

Load shaft **731** may rotate at a fixed speed, while boost compressor shaft **721** and engine core shaft **741** may rotate at faster speed (for example, upon an increase in required power on load shaft **731** by LDC **112** and/or generator **120**) and may rotate at variable speeds in relation to each other.

Allowing the speed of boost compressor shaft **721** to vary as the required power of LDC **112** and generator **120** varies may optimize boost compressor **315** and may allow boost compressor **315** to operate without the need for expensive variable geometry (inlet guide vanes) and handling bleed valves.

The power demand of LDC **112** and generator **120** may drive the boost provided by boost compressor **315**. As power required by LDC **112** or generator **120** increases, boost compressor **315** may speed up to operate APU **700** at a higher power. As power required by LDC **112** or generator **120** decreases, then the speed of boost compressor **315** may reduce. Thus, boost compressor **315** may provide as much pressure as needed. Differential gearbox **740** and the separation of boost compressor shaft **721** from turbine shaft **711** allows boost compressor **315** to have a different speed than power turbine **109**B.

By separating the rotation of HPC **105** and high-pressure turbine **109**A (connected by engine core shaft **741**) from power turbine **109**B (connected to differential gearbox **740** by turbine shaft **711**), may allow for a desired pressure ratio and allow APU **700** to operate at an efficient level, and provide a location at power turbine **109**B to inject excess load compressor air that is lower pressure than load compressor air **114**, as discussed in further detail below.

The components of APU **700** may be manufactured using conventional machining or casting.

In some embodiments, APU **700** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and the gas path of the gas turbine engine, in combination with a controller and one or more bypass valves for controlling and directing the flow of excess load compressor air **716** generated by LDC **112** (for example, excess load compressor air not required by ECS **130**).

Excess load compressor air **716** may be directed along an excess air pathway to be injected into the gas path of the gas turbine engine upstream of a turbine of the gas turbine engine, for example, adjacent one or more of high-pressure turbine **109**A and power turbine **1098** in turbine section **308**. Injection of excess load compressor air **716** into turbine section **308** may assist in the rotation of one or more of high-pressure turbine **109**A and power turbine **1098** of turbine section **308**.

In some embodiments, excess load compressor air **716** may be directed along an excess air pathway to be injected at combustor section **306** and/or any of the stages of compression upstream of combustor section **306**.

Excess load compressor air **716** may be directed along the excess air pathway to be injected at a location of lower pressure than load compressor air **114** within APU **300**, for example, upstream of power turbine **1098** and downstream of high-pressure turbine **109**A. Thus, backflow of excess load compressor air **716** may be avoided.

In some embodiments, a detector may detect the load of load compressor air **114** required by ECS **130**, and used to redirect load compressor air **114** and excess load compressor air **716** as needed.

Conveniently, redirecting excess load compressor air **716** into the gas path or power generation sections of APU **700** (such as compressor section **305**, combustor section **306** and turbine section **308**) may take advantage of the work applied to load compressor air **114** and may improve the overall performance of APU **700**.

FIG. **8** illustrates a turboprop (or turboshaft) engine **800**, in accordance with an embodiment. Turboprop engine **800** may include some of the same structure and components as the architecture of APU **700**, as described herein.

Ambient air is drawn into turboprop engine **800** by way of engine inlet **802**, which is then pressurized by boost compressor **315**. Boost compressor **315** generates a boosted compressor stream **316** for further compression by HPC **105** and then fed to combustor section **306**. Combustor section **306** may include, for example, combustor **106**, and compressed air is mixed with fuel and ignited for generating an annular combustion stream **307** of hot combustion gases. Turbine section **308** has high-pressure turbine **109**A and power turbine **109**B for extracting energy from the combustion gases which then exhaust to engine exhaust **110**.

Compressor section **305**, combustor section **306** and turbine section **308** form part of an engine core. Turboprop engine **800** defines a gas path through which gases flow, such intake air from engine inlet **802**, boosted compressor stream **316** and combustion stream **307**.

Turboprop engine **800** may include a turbine shaft **811**, a boost compressor shaft **821**, an output shaft **831** and high-pressure shaft **841**. Turbine shaft **811** connects to power turbine **109**B of turbine section **308**. Boost compressor shaft **821** connects to boost compressor **315**. Output shaft **831** may replace load shaft **731**, connecting to a propeller or shaft **860** by way of a (e.g., speed reduction) gearbox **850**.

Turbine shaft **811**, boost compressor shaft **821** and output shaft **831** are connected to a differential gearbox **840**. In some embodiments, differential gearbox **840** may have similar or the same structure and components as differential gearbox **440** or differential gearbox **740**, or other suitable differential gearbox.

High-pressure shaft **841** connects HPC **105** with high-pressure turbine **109**A.

The component configuration shown in FIG. **8**, in particular the use of differential gearbox **840**, may allow boost compressor shaft **821** and turbine shaft **811** to run at variable speeds, as compared to the generally fixed speed of output shaft **831**.

Variable boost speed (of boost compressor shaft **821**, and thus boost compressor **315**) may allow for more optimal compressor running lines, without the need for inlet guide vanes or handling bleed valves.

FIG. **9** is a schematic cross-section view of an auxiliary power unit (APU) **900** including a gas turbine engine for use on an aircraft to supply electric and pneumatic power to the aircraft systems as an auxiliary or secondary source of power, in which excess load compressor air **916** is directed to a recuperator **990**. Any other suitable engine may be employed.

As shown in FIG. **9**, APU **900** includes some of the same structure and components as the architecture of APU **100**, including inlet **102**, flow splitter **104**, engine stream air **103**A, load stream air **1038**, compressor **105**, combustor **106**, turbine section **108**, engine exhaust **110**, power shaft **111**, LDC **112**, load compressor air **114**, generator **120** and ECS **130**, as described herein.

HPC **105**, combustor **106** and turbine section **108** form part of the gas turbine engine, defining a gas path through which gases flow and exit the gas turbine engine as exhaust air **920**, as illustrated in FIG. **9**.

As shown in FIG. **9**, APU **900** may also include recuperator **990** downstream of the gas turbine engine. Recuperator **990** may be a heat exchanger used to extract heat from exhaust air **920** and preheat air such as excess load compressor air **916**, thus providing heat exchange between exhaust air **920** and excess load compressor air **916** prior to injecting the excess load compressor air **916** into the gas path of the gas turbine engine of APU **900**.

APU **900** may also include a bypass excess air pathway or conduit establishing fluid communication between LDC **112** and recuperator **990**, in combination with a controller and one or more bypass valves for controlling and directing the flow of excess load compressor air **916** generated by LDC **112**.

APU **900** may also include a bypass excess air pathway or conduit establishing fluid communication between recuperator **990** and the gas path of the gas turbine engine in combination with a controller and one or more bypass valves for controlling and directing the flow of heated excess load compressor air **918** from recuperator **990**.

In use, as LDC **112** rotates, LDC **112** will generate load compressor air **114**. As shown in FIG. **9**, if more load compressor air **114** is generated by LDC than is required by ECS **130**, unused excess load compressor air **916** may be released by a bleed valve (not shown) and directed to be injected into recuperator **990**.

Exhaust air **920**, upon passing through turbine section **108**, is directed to recuperator **990**. Excess load compressor air **916** is directed along an excess air pathway to be injected at recuperator **990**. Due to energy transfer within recuperator **990**, relatively cool excess load compressor air **916** may be heated by the relatively hot exhaust air **920**, forming heated excess load compressor air **918** and cooled exhaust air **922** which vents to engine exhaust **110**.

As also shown in FIG. **9**, heated excess load compressor air **918** may be directed along an excess air pathway to be injected, for example, adjacent one or more turbines in turbine section **108**. Injection of heated excess load compressor air **918** into turbine section **108** may assist in the rotation of one or more turbines of turbine section **108**.

In some embodiments, heated excess load compressor air **918** may be injected at other locations along the gas path of the gas turbine engine. For example, heated excess load compressor air **918** may be directed along an excess air pathway to be injected at combustor **106** and/or any of the stages of compression upstage of combustor **106**.

Heated excess load compressor air **918** may be directed along an excess air pathway to be injected at an area within APU **900** of lower pressure than load compressor air **114**. Thus, backflow of heated excess load compressor air **918** may be avoided.

In some embodiments, a detector may detect the load of load compressor air **114** required by ECS **130**, to redirect load compressor air **114** and excess load compressor air **916** as needed.

Conveniently, redirecting heated excess load compressor air **918** into power generation sections of APU **900** (such as turbine section **108**, combustor **106** and HPC **105**) may take advantage of the work applied to load compressor air **114** and may improve the overall performance of APU **900**. The use of heated excess load compressor air **918** into power generation sections of APU **900** may provide further efficiency improvement over the use of injecting unheated excess load compressor air. Capturing the exhaust stream energy from exhaust air **920** may improve the system efficiency of APU **900** and may reduce heat rejection to the surroundings and reduce fuel burn.

A low pressure of excess load compressor air **916** as compared to exhaust air **920** (for example, a pressure ratio of 4.5), may allow thinner walls to be used in recuperator **990**. A large temperature difference between excess load compressor air **916** and exhaust air **920** may also improve efficiency.

A recuperator such as recuperator **990** may be included with any of the APUs or gas turbine engines disclosed herein, such as APU **100**, APU **200**, APU **300**, APU **400**, APU **700**, turboprop engine **800**, to recuperate excess load compressor air using techniques described herein. In some embodiments, recuperator **990** and redirection of excess load compressor air **916** may be retrofitted on an existing gas turbine engine or APU.

Of course, the above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments are susceptible to many modifications of form, arrangement of parts, details and order of operation. The disclosure is intended to encompass all such modification within its scope, as defined by the claims.

What is claimed is:

1. A gas turbine engine system, comprising:

a boost compressor configured to compress air;

a high pressure compressor configured to receive compressed air from the boost compressor and further compress the compressed air, the high pressure compressor separately rotatable from the boost compressor;

a combustor in which the compressed air further compressed by the high pressure compressor is mixed with fuel and ignited to generate a stream of combustion gases; and

a turbine configured to extract energy from the combustion gases, the turbine being drivingly coupled to the boost compressor and to an output shaft via a differential gearbox configured to apportion an input torque from the turbine between a first output torque applied to the output shaft and a second output torque applied to the boost compressor,

wherein the differential gearbox comprises a first epicyclic gear set having a first sun gear rotatable about a first axis, a first ring gear rotatable about the first axis, one or more first planet gears, and a first carrier rotatable about the first axis; and the system further comprises:

a second epicyclic gear set having a second sun gear rotatable about a second axis, a second ring gear rotatable about the second axis, one or more second planet gears, and a second carrier rotatable about the second axis; and

a third epicyclic gear set having a third sun gear rotatable about a third axis, a third ring gear rotatable about the third axis, one or more third planet gears, and a third carrier; wherein:

the first sun gear is drivingly coupled to the boost compressor, the first ring gear is fixed, the first carrier ring is drivingly coupled to the second ring gear,

the second sun gear is drivingly coupled to the turbine, the second carrier is drivingly coupled to the third ring gear,

the third sun gear is drivingly coupled to the output shaft, and the third carrier is fixed.

2. The system of claim **1**, wherein the first output torque is different from the second output torque.

3. The system of claim **1**, wherein a rotational speed ratio between the output shaft and the turbine is different from a rotational speed ratio between the boost compressor and the turbine.

4. The system of claim **1**, wherein the output shaft is drivingly coupled to a load compressor, configured to generate compressed air for an environmental control system of an aircraft, and an electric generator.

5. The system of claim **1**, further comprising:

a load compressor drivingly coupled to the output shaft and configured to generate compressed air for an environmental control system of an aircraft; and

a conduit establishing fluid communication between the load compressor and an injection location in a gas path of the gas turbine engine to direct at least some of the compressed air generated by the load compressor to the injection location, the injection location being upstream of the turbine of the gas turbine engine.

6. The system of claim **4**, further comprising a recuperator configured to facilitate heat transfer from exhaust gas from the gas turbine engine to compressed air generated by the load compressor before injecting the compressed air generated by the load compressor in the gas path of the gas turbine engine.

7. The system of claim **1**, wherein the output shaft is drivingly coupled to a propeller via a reduction gearbox.

8. The system of claim **1**, wherein the first epicyclic gear seat is a first reduction gearbox.

9. The system ci claim **8**, wherein the third epicyclic gear set is a second reduction gearbox.

10. The system of claim **1**, wherein the differential gearbox includes a compound epicyclic gear set.

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